Popliteal Artery Repair in Massively Transfused Military Trauma Casualties: A Pursuit to Save Life and Limb

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Background: Popliteal artery war wounds can bleed severely and historically have high rates of amputation associated with ligation (72%) and repair (32%). More than before, casualties are now surviving the initial medical evacuation and presenting with severely injured limbs that prompt immediate limb salvage decisions in the midst of life-saving maneuvers. A modern analysis of current results may show important changes because previous limb salvage strategies were limited by the resuscitation and surgical techniques of their eras. Because exact comparisons between wars are difficult, the objective of this study was to calculate a worst-case (a pulseless, fractured limb with massive hemorrhage from popliteal artery injury) amputation-free survival rate for the most severely wounded soldiers undergoing immediate reconstruction to save both life and limb.

Methods: We performed a retrospective study of trauma casualties admitted to the combat support hospital at Ibn Sina Hospital in Baghdad, Iraq, between 2003 and 2007. US military casualties requiring a massive transfusion ($\geq$10 blood units transfused within 24 hours of injury) were identified. We extracted data on the subset of casualties with a penetrating supra or infrageniculate popliteal arterial vascular injury. Demographics, injury mechanism, Injury Severity Score, tourniquet use, physiologic parameters, damage control adjuncts, surgical repair techniques, operative time, and outcomes (all-cause 30-day mortality, amputation rates, limb salvage failure, and graft patency) were investigated.

Results: Forty-six massively transfused male casualties, median age 24 years (range, 19–54 years; mean Injury Severity Score, 19 $\pm$ 8.0), underwent immediate orthopedic stabilization and vascular reconstruction. There was one early death. The median operative time for the vascular repairs was 217 minutes (range, 94–630 minutes) and included all damage control proce-

dures. Combined arterial and venous injuries occurred in 17 (37%). Ligation was performed for no arterial and 9 venous injuries. Amputations (transtibial or transfemoral) were considered limb salvage failures (14 of 48, 29.2%) and were grouped as immediate ($\leq$48 hours, 5), early ($>$48 hours and $\leq$30 days, 6), or late ($>$30 days, 3). Limb losses were from graft thrombosis, infection, or chronic pain. Combined arterial and venous injuries occurred in 17 (37%). Ligation was performed for no arterial and nine venous injuries. For a median follow-up (excluding death) of 48 months (range, 23–75 months), the amputation-free survival rate was 67%.

Conclusions: This study, a worst-case study, showed comparable results to historical controls regarding limb salvage rates (71% for Iraq vs. 56–69% for the Vietnam War). Thirty-day survival (98%), 4-year amputation-free survival (67%), and complication-free rates (35%) fill knowledge gaps. Guidelines for managing popliteal artery injuries show promising results because current resuscitation practices and surgical care yielded similar amputation rates to prior conflicts despite more severe injuries. Significant transfusion requirements and injury severity may not indicate a life-over-limb strategy for popliteal arterial repairs. Future studies of limb salvage failures may help improve casualty care by reducing the complications that directly impact amputation-free survival.

Key Words: Vascular trauma, Massive transfusion, Damage control, Resuscitation, Combat, Wartime, Military.

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Traumatic injury to the popliteal artery remains a challenging problem on the modern battlefield and is frequently associated with more complications compared with other vascular injuries.[1] These wounds can bleed severely, and historical outcomes have demonstrated high rates of amputation associated both with ligation (72%) and repair (32%).[2–5] During the Korean War, attempts at vascular repair were common; however, evacuation and treatment delays for resuscitation efforts made popliteal arterial wounds associated with fracture an inevitable indication for immediate amputation.[3] During the Vietnam War, popliteal injuries accounted for greater than half of all major limb amputations performed, and such casualties sustained more associated injuries (fracture, nerve, and vein injuries) and complications than any other single group of vascular injured casualties.[5] In the current conflict, more casualties are now surviving their injuries and presenting with severely injured limbs that prompt immediate limb salvage decisions in the midst of life-saving maneuvers.[6] Damage control principles are frequently applied to vascular injuries, and damage control resuscitation (DCR) has become an increasingly accepted paradigm in caring for the seriously wounded.[7–9] However, the mortality of the massively transfused casualty remains

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20% to 40% and can generate uncertainty when faced with a decision to repair a wound with a historically high failure rate.[10,11,12] Knowledge of when an amputation should be performed in this setting is difficult and not well evidenced. Moreover, misguided judgment or inexperience may result in multiple operations, eventual amputation, or worse yet, loss of life.[4] Therefore, a modern analysis may refine surgical judgment because previous limb salvage strategies were limited by resuscitation and surgical techniques. We hypothesize that despite the potential for delayed amputation, current transfusion requirements and injury severity may not be an indication to resort to a life-over-limb approach for these popliteal arterial injuries.

The objective of this study was to calculate a worst-case amputation rate, complication-free rate, and amputation-free survival for the most severely wounded soldiers undergoing popliteal arterial reconstruction during the initial "damage control" operation after penetrating combat injuries. Clinically, the worst cases are those casualties with massive transfusion requirements and pulseless fractured limbs involving the popliteal artery. These cases comprise the study group to report the outcome for the most difficult of combat-related popliteal arterial injury. Additionally, this study aimed to provide insight into the impact of current clinical guidelines for immediate limb salvage procedures, and to determine whether current resuscitation practices and surgical care yield similar amputation rates of prior conflicts for this injury.[13,14]

PATIENTS AND METHODS

Study Design

We designed a retrospective study to evaluate the outcome of massively transfused military casualties with popliteal artery injury. This was performed on all trauma casualties admitted to a single combat support hospital (CSH) located at Ibn Sina Hospital in Baghdad, Iraq, between January 2004 and December 2006. A vascular trauma registry (nontransfusion data) was also retrospectively evaluated from the same hospital during 2003 and 2007. US military casualties with a popliteal arterial vascular injury who underwent an attempt at limb salvage were identified whether they had received a massive transfusion (defined as 10 or more units of blood within 24 hours). The data presented here were obtained under a human-use protocol that received the Institutional Review Board approval through the Department of Clinical Investigation at Brooke Army Medical Center at Fort Sam Houston, TX.

Data Sources

Theater transfusion records maintained within the US Department of Defense Armed Services Blood Program Office database in Falls Church, VA, were used to identify massively transfused casualties and individual blood products. The Joint Theater Trauma Registry (JTTR) maintained at the US Army Institute for Surgical Research at Fort Sam Houston, TX, was used to determine baseline patient demographics and determine outcomes for evacuated casualties. For US military casualties discharged from the hospital before 30 days, outpatient visits were noted in the Joint Patient Tracking Application, which provides information on location and status of soldiers near real-time through a Web-based application. Mortality and dates of death were cross-referenced with Social Security Death Index records and listing of casualties provided on the online Web site of Iraq Coalition Casualty Count (www.icasualties.org). Individual patient chart review was performed on inpatient records to verify vitals, laboratory reports, blood product transfusions, and outcomes before evacuation or transfer from the CSH. Such charts were viewed directly or by using the Patient Administration Systems and Biostatistics Activity system, which receives all inpatient records from deployed medical units. Blood product usage and timing of blood product administration were identified from the chart and were compared against the JTTR and the Armed Services Blood Program Office Blood Bank transfusion record. Discrepancies were reconciled by comparing the times recorded on blood transfusion slips, anesthesia records, intensive care unit (ICU) records, operative reports, and discharge summaries. Most discrepancies occurred in the context of missing or incomplete blood transfusion slips, double counting of carbon copies of blood transfusion slips, misdocumentation of blood products (e.g., red blood cells [RBCs] recorded as fresh frozen plasma [FFP] or FFP recorded as RBCs), and inaccurate documentation on anesthesia records or failure to attribute emergency release blood products to the specific recipient by the blood bank. The comparison of multiple databases with correlation to the patient record represents the most accurate and complete data set possible.

Data Collection

Methods of popliteal vascular reconstruction, specific vessel (arterial and venous), side of injury, operative time, time in hospital, time in ICU, and all subsequent graft failures (immediate and delayed) were carefully documented. Arterial injury, one that requires removal of thrombus to restore arterial flow or suture repair to stop hemorrhage, is differentiated as a subset of the definition of wound, and that includes artery, soft tissue, nerve, and osseous structure. After this identification, patient charts were also evaluated for age, sex, mechanism of injury, documented injuries, Glasgow Coma Scale score, and admission vital signs. A systolic blood pressure (SBP) <110 mm Hg, respiratory rate >20 per minute, or a pulse >100 bpm fulfilled the criteria for hypotension, tachypnea, and tachycardia. Changes in heart rate (HR), temperature, and SBP and diastolic blood pressure (DBP) between from the emergency department to the measured time points in the ICU are reflected as ΔHR, ΔT, ΔSBP, and ΔDBP, respectively.

Admission laboratory tests and changes (Δ) over time points were documented. Blood product administration at 24 hours (RBC, FFP, cryoprecipitate [cryo], and platelet [PLT]) and recombinant factor VIIa administration and dosage were also noted. Crystalloids and colloids fluids administered in the first 24 hours were incompletely documented in many casualties. Taking into account the units of RBCs contained within a unit of fresh whole blood (FWB), a calculation of the sum of blood units given within the first 24 hours after admission was calculated (sum of blood units = RBC + FWB). Accounting for the amount of plasma contained within FWB and apheresis platelet (aPLT) units (each containing the equivalent of 1 unit of plasma), plasma ratios (%) were calculated as (FFP + aPLT + FWB)/(RBC + FWB) × 100. Abbreviated Injury Scale and Injury Severity Scores

(ISSs) were centrally scored and calculated by trained research nurses and staff using ISS-98 after patient discharge.

A Level I facility was defined as a far forward casualty collection site resourced for immediate lifesaving measures (airway and hemostasis), immobilization, and evacuation. A Level II facility has expanded resources for resuscitation and limited capability (simple repair or temporary vascular shunt) for vascular reconstruction. Level III facilities are resourced to provide all categories of surgical care within a theater of military operations and are the subject of this report. The study group was taken directly to the Level III hospital or evacuated through Level I and Level II facilities before definitive popliteal repair. US soldiers were tracked for survival because they reached higher echelons (Levels IV and V) of care for definitive treatment and rehabilitation performed in Europe and the United States. Secondary outcomes, including amputation, thrombotic and infectious graft failures, vascular reinterventions, complications, cause of death from central nervous system injury, exsanguinations, airway failure, multiple-system organ failure (in casualties surviving >24 hours), and arterial and venous embolism were evaluated using the JTTR and available inpatient records from Ibn Sina Hospital, US military hospitals in Germany, and the continental United States. No strict definitions for these adverse events were used but were simply counted if so stated in the medical progress notes.

Detailed data on amputees, including anatomic location of amputation(s) and mechanism of injury, were identified using the military amputee database. A major amputation was defined as loss of a limb at or proximal to the ankle. The presence and indication of an amputation ipsilateral or contralateral to a popliteal vascular repair was documented. The date of amputation was noted and also grouped as immediate (≤48 hours), early (>48 hours and ≤30 days), or delayed (>30 days). Limb salvage was defined as any lower-extremity popliteal vascular wound that was repaired with an expectation of permanent limb viability. Limb salvage was considered a failure if an arterial repair was made to restore perfusion to a pulseless limb and the patient died of wounds or if the limb was amputated above the ankle at any time during the postreconstruction follow-up period of the study. If the initial graft failed (infection, rupture, thrombosis, stenosis, or reintervention by thrombectomy, revision, or replacement) but the limb remained viable, this condition was reported as a complication. Graft failures and amputation data were used to calculate the amputation rate (proportion of ipsilateral amputations divided by the number of limbs repaired) and the amputation-free survival (alive casualties minus the proportion of ipsilateral amputees divided by all casualties) for all limb salvage failures.

Descriptive statistics are used to report the 30-day mortality and overall complication rate for the study group. Continuous data are presented as mean (±standard deviation) for parametric data or median (range) for nonparametric data, as indicated. Paired *t* testing was performed to compare the vital signs and laboratory studies in the emergency department, with those at ICU admission and also at 24 hours. Statistical significance was set at $p < 0.05$ for comparisons. Statistical analysis was performed with SPSS 15.0 (SPSS, Inc., Chicago, IL).

RESULTS

During this study period, 46 massively transfused casualties underwent popliteal arterial vascular reconstructions of 48 pulseless limbs. All casualties arrived at a single CSH between June 2003 and October 2007 for the surgical management of a popliteal artery injury. From January 2004 to December 2006, 8,618 casualties were admitted, of which 2,024 (23%) received blood transfusions. There were 694 (8.1%) who received >10 units of blood (RBC + FWB) in 24 hours. Of these, 285 were US casualties, and 42 (14.7%) of them had a popliteal arterial vascular injury. The four additional casualties who had a massive transfusion and popliteal injury were added to this cohort (1 in 2003 and 3 in 2007) based on an expanded search using existing vascular registry records of casualties from this US military hospital. Figure 1 details the study profile for these casualties.

The study group consisted entirely of the US service members. All were men with a median age of 24 years (range, 19–54 years). The mean (±standard deviation) ISS and median operative time were 18.8 ± 7.97 and 217 minutes (range, 94–630 minutes). Popliteal vessel injuries were all from penetrating trauma and consisted of gunshot wounds or high-energy explosions. All vascular injuries (Fig. 2) were associated with large soft-tissue wounds and fractures that required external fixation and vacuum-assisted closure. Because of the short prehospital transport time (≈30 minutes), extremity ischemic times were limited, although many (18 [39%]) were referred from a Level I (10 [55%]) or Level II (8 [45%]) facility for the definitive repair of the vascular injury. All casualties survived the immediate postoperative period (≤48 hours); however, there was one death from abdominal sepsis and multiple-system organ failure during the 30-day period. The median follow-up in the study period was 48 months (range, 23–75 months).
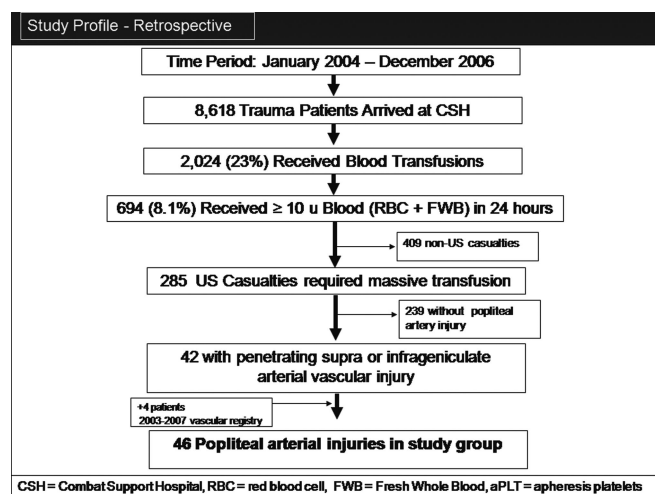

Figure 1. Summary data of the study group, massively transfused trauma patients from a single US military hospital in Baghdad, Iraq, who sustained a penetrating popliteal artery injury during combat operations.
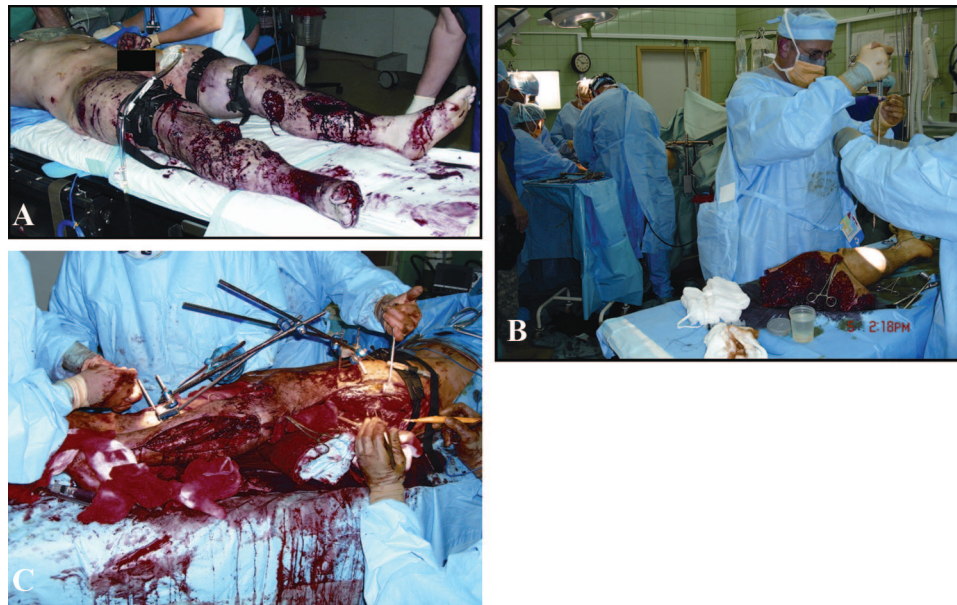
Figure 2. (*A*) Prehospital tourniquets have decreased hemorrhagic death on the modern battlefield and increased the number of potentially salvageable lower-extremity fragmentation wounds with popliteal artery injuries. (*B*) COL (ret) John B. Holcomb, MD, FACS, harvests a saphenous vein from a contralateral amputated limb to reconstruct an injured artery and vein in a patient on the adjacent table. A two-team approach allows for rapid repair of vascular injuries and may enhance limb salvage in the modern era. (*C*) Current military lower-extremity vascular injuries frequently involve the artery and vein, are associated with fractures, and are often bilateral. This photograph depicts the use of prehospital tourniquets, hasty external fixation, and fasciotomy performed, all prior to isolation and repair of the popliteal vascular injury.

TABLE 1. Demographics and Averaged Physiologic Parameters on Emergency Department Arrival

Variable	All Patients (n)
Age (yr), median, range	24, 19–54 (46)
Injury Severity Score (ISS98)	18.8 ± 7.97 (46)
Glasgow Coma Scale score	11.28 ± 5.02 (39)
Systolic blood pressure (mm Hg)	104.24 ± 31.18 (41)
Diastolic blood pressure (mm Hg)	55.79 ± 18.01 (41)
Respiratory rate	21.41 ± 8.47 (38)
Heart rate (beats per minute)	111.98 ± 21.68 (41)
Temperature (°F)	96.48 ± 2.88 (41)
pH	7.22 ± 0.2 (38)
Base deficit (mEq/L)	9.90 ± 8.76 (39)
Hemoglobin (g/dL)	10.63 ± 2.35 (41)
Platelet count (1,000/μL)	214.58 ± 99.92 (38)
Prothrombin time (PT)	18.76 ± 10.38 (38)
International normalized ratio	1.84 ± 1.02 (41)
Creatinine (mg/dL)	1.39 ± 0.35 (38)

Data are mean ± standard deviation unless otherwise specified.

Physiologic Presentation

Baseline demographics and admission physiology (Table 1) were similar to our prior reports and consistent with hemorrhagic shock based on the admission base deficit and history of blood loss from an arterial injury.[15,16] The admission physiology shows that this group of casualties arrived acidotic (mean pH, 7.22; mean base deficit, −10), coagulopathic (mean prothrombin time, 18.8; mean international normalized ratio [INR], 1.8), and mildly hypothermic (mean temperature, 96.5°F). Together with tachycardia, tachypnea, and relative hypotension, these physiologic derangements were consistent with moderate to severe blood loss. Physiologic improvements in the clinical condition were reflected by positive changes in vital signs and normalization of aberrant laboratory studies when comparing emergency department arrival (Table 1) with ICU admission at the conclusion of the vascular reconstruction. The physiologic response to DCR was most significantly reflected early at ICU admission but was sustained during the first 24 hours. This DCR strategy showed statistically significant improvements in HR, blood pressure, and correction of coagulopathy (ΔHR 10, ΔT 1.4, ΔSBP 31, ΔDBP 16, and ΔINR 0.4; $p <$ 0.05), and the results are summarized in Table 2.

Transfusion Requirements

All 46 casualties in the study group had received a massive transfusion (≥10 units of blood) as part of the 24-hour resuscitation in the management of combat-related injuries. This represented 15% of all massive transfusions (42 of 285) in US casualties during a 3-year period in this military hospital. The mean total blood products transfused (RBC + FWB) for the study group was 30 units, and the mean plasma:RBC ratio was 1:1.5. Fifteen (33%) casualties received a mean of 8 units of warm FWB in the operating room. Approximately half (21 of 46, 46%) received recombinant factor VIIa during the emergency room resuscitation with one to two additional doses (90–120 μg/kg) given intraoperatively. The mean crystalloid resuscitation was 11 L. The mean transfusion requirements are summarized in Table 3.

TABLE 2. Physiologic Recovery After Popliteal Vascular Reconstruction

Variable	ED Arrival (n)	ICU Admission (n)	24-hr Physiology (n)	ED to ICU*	P	ICU to 24th hr*	P
Systolic blood pressure (mm Hg)	104.24 ± 31.18 (41)	135.38 ± 29.68 (38)	125.08 ± 24.68 (25)	31.14	<0.01	−10.3	0.72
Diastolic blood pressure (mm Hg)	55.79 ± 18.01 (41)	71.97 ± 11.90 (38)	66.68 ± 13.51 (25)	16.18	<0.01	−5.29	0.32
Respiratory rate	21.41 ± 8.47 (38)						
Heart rate (beats per minute)	111.98 ± 21.68 (41)	101.38 ± 22.21 (38)	106.40 ± 15.16 (25)	−10.6	<0.01	5.02	0.65
Temperature (°F)	96.48 ± 2.88 (41)	97.97 ± 1.64 (38)	100.12 ± 1.31 (25)	1.49	<0.01	2.15	<0.01
pH	7.22 ± 0.2 (38)						
Base deficit (mEq/L)	9.90 ± 8.76 (39)						
Hb (g/dL)	10.63 ± 2.35 (41)	10.08 ± 2.77 (38)	11.05 ± 1.93 (25)	−0.55	0.37	0.97	0.53
Platelet count (1,000/μL)	214.58 ± 99.92 (38)	74.82 ± 40.97 (38)	67.38 ± 15.38 (25)	−139.76	<0.01	−7.44	0.71
Prothrombin time	18.76 ± 10.38 (38)	14.08 ± 5.45 (38)	13.11 ± 4.03 (25)	−4.68	0.02	−0.97	0.49
INR	1.84 ± 1.02 (41)	1.44 ± 0.59 (38)	1.34 ± 0.40 (25)	−0.4	0.02	−0.1	0.49
Creatinine (mg/dL)	1.39 ± 0.35 (38)	1.17 ± 0.27 (38)	1.19 ± 0.25 (25)	−0.22	0.33	0.02	0.43
OR time (min), range		217, 94–630 (46)					
Total time in ICU (hr)			20.46 ± 20.06 (38)				
Total time in level III (hr)			29.01 ± 25.7 (39)				

Hb, hemoglobin; INR, international normalized ratio; ED, emergency department; ICU, intensive care unit, OR, operating room.

* Comparison of physiologic differences from ED arrival to ICU admission and 24 hr later after damage control and reconstruction.

P values are derived from standard paired *t* tests.

Data are mean ± standard deviation unless otherwise specified.

Vitals signs and laboratory studies were taken immediately on ICU admission.

TABLE 3. Summary of Mean Transfusion Requirements for 46 Massively Transfused Casualties With Popliteal Arterial Injuries

Blood Component	24-hr Totals
Total blood products*	29.9 ± 15.3 units
Fresh frozen or thawed plasma	18.7 ± 10.5 units
Plasma:RBC ratio	1:1.59
Cryoprecipitate	12.9 ± 14.0 units
Platelets (6 pack)	2.4 ± 2.0 units
Crystalloid (L)	11.9 ± 6.5
Receiving fresh whole blood	32.6% (15/46)
Receiving recombinant factor rFVIIa	45.6% (21/46)

    * Packed RBCs + whole blood.

Initial Vascular Repair

There were 48 popliteal artery injuries in 46 casualties. All underwent immediate revascularization for limb salvage using a reversed saphenous graft (33 [69%]), lateral suture (9 [19%]), saphenous vein patch (1 [2%]), end-to-end anastomosis (1 [2%]) or thrombectomy (4 [8%]). Frequently, the wounds required management of a concomitant venous injury (17 of 46, 37%) either by ligation (9 of 17, 53%), saphenous vein graft (6 of 17, 35%), or suture repair (2 of 17, 12%). The median operative time required for these procedures was 217 minutes (range, 94–630 minutes). These durations include the time of the vascular reconstruction, explorations, fasciotomy, and external fixation performed by a second surgical team or an assisting orthopedic surgeon. Eight (17%) of the 46 casualties had extensive contralateral lower-extremity wounds that re-

quired immediate amputation for the degree of tissue loss or to control hemorrhage. The distribution, management, and outcome of these vascular injuries are shown in Table 4.

Amputation Rate

Among the 48 reconstructed limbs, 14 (29%) limb salvage failures occurred, yielding an amputation outcome. The amputation levels were transfemoral (8 [57%]), transtibial (4 [29%]), and through the knee (2 [14%]). Immediate amputations (<48 hours) were all because of graft thrombosis (5 of 14, 36%). Early amputations that occurred between 48 hours and 30 days (6 of 14, 43%) were related to subsequent graft thrombosis, infection, or progressive soft-tissue injury. Delayed amputations (3 of 14, 21%) were because of orthopedic complications, such as osteomyelitis, pain, or poor function. One patient underwent elective amputation nearly 1 year after the injury for functional limitations. There were 8 (17%) casualties with contralateral traumatic amputations. Three of the 14 limb salvage failures were in casualties who had required an immediate contralateral amputation; thus, they subsequently became bilateral amputees (Table 4).

Complication Rate and Amputation-Free Survival Rate

There were no intraoperative or early (<48 hours) postoperative deaths, but one patient with a viable limb died of abdominal sepsis and multiple-system organ failure on postoperative day 15. Thirty of the 46 casualties experienced a significant complication relating to the immediate popliteal artery revascularization. Major complications included infection (12 [26%]), deep venous thrombosis or pulmonary embolism (11 [23%]), respiratory or renal failure (7 [15%]), and

TABLE 4. Distribution, Management, and Outcomes of 65 Combat-Related Popliteal Vascular Injuries in 46 Patients

Patient	Side Repaired	Arterial	Venous	Failures	Day	Reason	Immediate CL Amps	Complications	Survival	Follow-Up
1	Left	Saphenous graft		BKA	<2	Thrombosis		Amputation	Yes	36
2	Left	Saphenous graft		AKA	<2	Thrombosis		Amputation	Yes	44
3	Right	Saphenous graft	Ligation	AKA	<2	Thrombosis		ARF, amputation	Yes	65
4	Right	Saphenous graft		AKA	<2	Thrombosis	BKA	Bacteremia, amputation	Yes	62
5	Right	Saphenous graft		BKA	3–30	Thrombosis	BKA	Ventilator-associated pneumonia	Yes	41
6	Right	Saphenous graft							Yes	58
7	Right	Saphenous graft		AKA	21	Thrombosis		HIT, PE, graft thrombosis, respiratory failure	Yes	59
8	Left	Saphenous graft						Wound infection	Yes	35
9	Left	Saphenous graft						DVT	Yes	56
10	Left	Saphenous graft	SV					Graft rupture, replaced with ePTFE, thrombosis, sepsis, DVT	Yes	44
11	Left	Saphenous graft						MSOF	No, POD15	58
12	Left	Saphenous graft	SV	AKA	10	Graft rupture		Bacteremia, DVT, CVA, amputation	Yes	37
13	Left	Saphenous graft							Yes	55
14	Left	Primary repair	Ligation					DVT	Yes	49
15	Left	Primary repair	Ligation				AKA	*Acinetobacter* bacteremia & acute renal insufficiency	Yes	37
16	Left	Primary repair							Yes	49
17	Left	Saphenous graft						DVT	Yes	47
18	Left	Vein patch					Hip disarticulation	DVT	Yes	63
19	Left	Saphenous graft	SV				AKA		Yes	54
20	Left	Thrombectomy							Yes	55
21	Left	End to end							Yes	57
22	Right	Saphenous graft							Yes	52
23	Right	Saphenous graft							Yes	54
24	Left	Saphenous graft	Ligation					Revised stenosis <30 days	Yes	52
25	Right	Saphenous graft	Ligation	AKA	7	Thrombosis		Bacteremia, amputation	Yes	36
26	Right	Primary repair	Ligation					Unsuccessful thrombectomy, wound infection	Yes	33
27	Right	Saphenous graft		AKA	<2	Thrombosis	AKA	Wound infection, amputation, PE	Yes	35
28	Right	Thrombectomy		TKA	6	Thrombosis		Respiratory failure, amputation	Yes	42
29	Right	Primary repair	Ligation				AKA		Yes	58
30	Right	Saphenous graft	Ligation						Yes	53
31	Right and left	Saphenous graft (2)	SV						Yes	42
32	Right	Primary repair		BKA	175	Pain		DVT, ARF, amputation	Yes	60
33	Right	Primary repair						*Klebsiella* osteomyelitis	Yes	38
34	Right and left	SV and primary (2)						DVT-left popliteal	Yes	44
35	Right	Saphenous graft	SV				AKA	DVT, SVG replaced with ePTFE (4 wks)	Yes	41
36	Right	Saphenous graft							Yes	56
37	Right	Thrombectomy						DVT/PE	Yes	44
38	Right	Thrombectomy						Bacteremia	Yes	36
39	Left	Saphenous graft		AKA	4	Soft tissue		Amputation	Yes	28
40	Left	Saphenous graft		TKA	341	Poor function		Amputation	Yes	75

TABLE 4. Distribution, Management, and Outcomes of 65 Combat-Related Popliteal Vascular Injuries in 46 Patients (continued)

Patient	Side Repaired	Arterial	Venous	Failures	Day	Reason	Immediate CL Amps	Complications	Survival	Follow-Up
41	Left	Primary repair	Ligation						Yes	63
42	Right	Saphenous graft	SV						Yes	50
43	Left	Saphenous graft		BKA	288	Osteomyelitis		Amputation	Yes	47
44	Left	Saphenous graft	Suture						Yes	26
45	Left	Saphenous graft	Ligation						Yes	23
46	Right	Saphenous graft						Graft thrombectomy	Yes	43
Totals		48	17	14			8			

	Amputation Rate	Amputation-Free Survival	Complication Rate	30-Day Survival	Average Follow-Up
n = 46	14/48	31/46	30/46	n = 45	
%	29.17%	67.39%	65.20%	97.82%	48 months

AKA, above-knee amputation; BKA, below-knee amputation; suture, primary repair; end-end, end-end anastomosis; SV, saphenous vein; TKA, through-knee amputation; ARF, acute renal failure; ePTFE, prosthetic graft; DVT, deep venous thrombosis; PE, pulmonary embolism; MSOF, multiple-organ system failure; CVA, cerebrovascular accident; HIT, heparin-induced thrombocytopenia; SVG, saphenous vein graft; POD, postoperative day.

TABLE 5. Historical Amputation Rates for Popliteal Artery Repair

Conflict	Popliteal	Ligation	Amputation	Repair	Amputation
World War II (2471)	502	499	364/499 (73%)	3	1 (33%)
Korean War (304)	79	11	8/11 (73%)	68	22 (32%)
Vietnam War (365)	77	2	2/2 (100%)	75	25 (33%)

graft revision secondary to rupture or stenosis (3 [6%]). One graft dehiscence resulted in amputation, whereas the other was successfully managed with a prosthetic replacement. Twelve of the 33 limbs with saphenous vein grafts were amputated and 2 (10%) of the remaining 21 were replaced with prosthetics. Both prosthetic grafts were subsequently thrombosed, resulting in diminished ankle brachial indices with stable claudication symptoms that are managed medically. The overall complication rate among 30 casualties who suffered a major complication or failed attempted limb salvage was 65%. The amputation-free survival in this study was 67%.

DISCUSSION

For an injury deemed a worst case, a severely injured battle casualty with a popliteal artery injury requiring massive resuscitation, the casualty survival rate and limb salvage rate remain at historic highs with DCR and vascular repair techniques despite worsening injuries. These casualties were characterized by high ISS, hemorrhagic shock, open fractures, extensive soft-tissue wounds, and concomitant venous injury. The use of tourniquets, modern body armor, and hemostatic resuscitation practices have reduced case fatality rates and increased both the incidence and severity of lower-extremity vascular injury presenting for management in the US military hospitals of Iraq and Afghanistan.[6,17–19]

The strength of this study is the coupling of the amputee data and trauma registry data (JTTR) to establish the long-term amputation rate and amputation-free survival rate for popliteal artery injury. These rates may be helpful for future deployed surgeons in making life-over-limb decisions for those with significant transfusion requirements. To our knowledge, this study reports the largest contemporary analysis of massively transfused US military casualties undergoing simultaneous DCR and popliteal arterial vascular reconstruction. This study calculates a long-term amputation rate (29%) and a complication-free rate (35%) and shows a promising amputation-free survival (67%) associated with refined resuscitation practices that seem to allow the pursuit of both simultaneous life-saving and limb-saving interventions in a vascular bed traditionally associated with highest rates of failure. Although exact comparisons between wars are difficult, it seems that current resuscitation practices and surgical care for difficult popliteal vascular injuries have improved on the amputation rates of prior conflicts (Table 5).

Although explosive wounding patterns have remained similar to those of past conflicts, the incidence of vascular injuries in Iraq has been reported to be as much as twice that of the Vietnam War.[6] Of the body regions, 50% to 70% of wounds involve the extremities; however, current estimates of extremity wounding in surviving casualties may have been affected by changing battlefield tactics, more life-saving use of prehospital tourniquets, improved vehicle and body armor, and more rapid evacuation to a hospital capable of improved resuscitation and complex reconstruction.[16,18,20]

During the Korean and Vietnam campaigns, popliteal arterial injuries constituted 22% to 27% of the vascular injuries and led to the majority of subsequent limb salvage failures and other complications. Although repair of popliteal vascular injuries during the Korean and Vietnam Wars has been associated with a near 50% reduction in the amputation rate associated with ligation compared with World War II, many factors associated with limb loss from this important injury remain unclear.[2,3,5] Traumatic lower-extremity amputations and severe lower-limb injury are associated with considerable psychologic distress for both the survivors and their family members.[21] Recent publications on damage con-

trol, resuscitation, and novel surgical adjuncts have shifted contemporary public awareness away from amputation acceptance to one of limb salvage as the newly expected norm.[22] Therefore, it is essential to report on this 4-year follow-up comprising early, mid, and delayed lower-extremity amputation outcomes associated with failed limb salvage efforts among the most severely injured US battle casualties. During World War II, DeBakey and Simeone[2] reported that arterial ligation is not a procedure of choice but rather one of the necessity to control bleeding and to prevent a hemorrhagic death. Despite surgical improvements in the 1950s, resuscitation delays of 10 hours to 15 hours became the barrier to successful repair in the Korean War and many of these limbs underwent eventual amputation.[3] In the Vietnam War, Rich and Hughes reported their vascular case experience and noted significantly shorter casualty evacuation, attended casualty resuscitations often with >4,000 mL of blood, and emphasized the value of repairing both popliteal arterial and venous injury with autologous grafts. From the Vietnam Vascular Registry data, Rich concluded that nearly half of all amputations and most of the thrombotic complications were with injuries to the popliteal artery. The reported amputation rate during the Korean War was 32% and ranged from 31% to 48% during the Vietnam War.[3,4,23] Rich and Baugh reported the largest series of 150 repairs with 48 amputations and achieved a rate (32%) comparable with the Korean conflict.[4,5] Woodward et al. recently described the early limb salvage rate (defined as those reaching the United States with a viable limb) in 44 popliteal arterial injuries (44 casualties) during a 32-month period (2004–2007) from the Air Force Theater Hospital in Balad, Iraq. Most casualties (28 [62%]) had combined arterial and venous injury. There were two deaths but neither death was associated with the repaired vascular injury or required amputation before death. In this contemporary Air Force series, only 15 (33%) casualties were from the United States, and very limited data exist for resuscitation, injury severity, and amputation rates after the first week. Their reported early mortality of 5% (2 of 44) is similar to the findings of 2% (1 of 46) in this study. It is interesting to note that in Korea, 13% died early, and 1.7% mortality was reported for all vascular injuries in Vietnam whether deaths were early or late. The early amputation rate of 14% in those with popliteal artery injuries described by Woodward et al. was related to either early graft failures or progressive soft tissue injury, a major factor influencing the decision to amputate.[4,24] Therefore, this study fills a gap by providing resuscitation data and modern amputation rates with long-term follow-up of US military casualties after a severe vascular injury.

Accepted wisdom about the mortality of casualties presenting with the lethal triad of coagulopathy, acidosis, and hypothermia can lead to reluctance to repair lower-extremity vascular wounds in casualties that may require massive transfusions to reverse severe hemorrhagic shock. In fact, traditional damage control concepts emphasize early hemostasis, a limited initial operation, and reversal of physiologic derangements before restoring normal anatomy. However, the goals of resuscitation and surgery were not as compartmentalized in prior conflicts as they are currently. Surgical teaching of the Korean War era noted that "rushing an improperly resuscitated patient to surgery in an attempt to save a limb may result in loss of life."[3] Resuscitation outcomes in the most severely wounded casualties from a surgical hospital in Korea during 1952 were reported in 89 battle casualties, each of whom required a minimum of 15 pints of blood (transfusions of >1.5 times the expected body blood volume). The authors advocated for aggressive resuscitation and demonstrated that massive transfusions were used more frequently compared with the former practices of World War II and emphasized that rarely was there evidence of over transfusion.[25] Artz et al. also demonstrated a policy of early and liberal transfusion practices by showing that the amount of blood given preoperatively was nearly the same in amount as given during the operation. The average transfusion was 24 pints, and some casualties received 30, 40, and even 50 pints of blood within the first 24 hours. When hemorrhage was controlled, the case fatality rate was 14% (4 of 29) for casualties with lower-extremity arterial wounds, and the prognosis was predicted better by the amount of transfused blood than by the degree of hypotension at admission.[25] The Army Medical Research Board conducted a study of the physiologic effects of severely wounded battle casualties and concluded that "one should not speak of resuscitation and surgery, for surgery [to control hemorrhage] is a vital part of resuscitation."[25] Survival during the Korean War was undoubtedly influenced by shorter evacuation times than during World War II; however, the vigorous use of whole blood was also credited heavily at that time for improved survival.[25] Acceptance of DCR in the current war has led to effective resuscitation practices, enabling surgeons to reconsider arterial repair at the time of other damage control maneuvers. In other words, battle casualty survival is at a historic high, and DCR has played a major role in the acknowledged survival advantages because case fatality rates (as a percentage of fatalities among all wounded) have declined from 19.1% and 15.8% during World War II and Vietnam to the present 9.4% in Iraq.[17,26] DCR was recognized as one of the US Army's top 10 innovations of 2007.

Although differences between military and civilian trauma may exist, overall management and early outcome are not dissimilar to larger civilian studies like the one from Memphis that had an overall amputation rate of 24% in 102 casualties. Because this study evaluated the outcome of seriously wounded from a single center over an extended period, with longer evacuation times than civilian centers, a rate of 29% is comparable despite the war challenges. Most of the amputations in this study occurred within a 30-day period; yet, delayed failures from pain, infection, and poor function may provide important information that may influence the early reconstruction decisions. Stansbury et al.[26] recently estimated that delayed amputations accounted for only about 5% of the amputations performed in military personnel, usually from nonunion or infection. Mangled extremity severity score is an objective method to predict favorable outcome based on age, degree of skeletal and soft-tissue injury, duration of ischemia, and the presence of shock.[27] However, other civilian studies suggest that scoring

systems have limited usefulness in predicting functional recovery after limb reconstruction.[28] In a recent report of United Kingdom military casualties, mangled extremity severity score did not help to decide whether or not an amputation was appropriate, and in particular, the age was not relevant. Most amputations in this United Kingdom study were performed when an ischemic limb was present and the general condition of the casualty precluded the lengthy reconstruction required for salvage.[29] To our knowledge, a scoring system was not applied to the casualties in this study to help decide on limb salvage or immediate amputation. Reasons for immediate amputation remain unclear and underscore the need to develop a data collection sheet that may better categorize and refine the working definition of an immediate amputation (Appendix). Although many of the repairs in this study resulted in long-term technical success (viable limb with a patent vessel), the functional outcomes and quality of life factors compared with casualties with modern prosthetic limbs remain unknown.

More modern armies have greater mobility and can provide more forward care on the battlefield. Temporary arterial shunts and tourniquets have advanced the management of vascular injuries because tourniquets have improved battle casualty survival, and shunting has permitted successful repair once casualties are transferred to a facility with adequate resources.[20,30] Military doctrine on hemorrhage control has changed significantly compared with the Vietnam War, where tourniquet use was limited and pressure dressings were considered adequate.[5] In a preliminary report of the Vietnam Vascular Registry, shunts were used only in the management of three carotid injuries.[5] Limb loss in the present conflict was not associated with shunt thrombosis, and when shunt failure occurred, thrombosis was usually in distal vessels that could tolerate ligation.[31] The use of shunts has been a safe and effective damage control technique and may be preferable to attempted popliteal reconstruction under more austere conditions.[30]

The management of popliteal arterial injuries in the current war was similar to that of the Vietnam War in that repair was preferred over ligation and that vein grafts were preferred over prosthetic grafts. The strong preference for a saphenous vein graft in this study was based on the poor historical results of prosthetic material when used in contaminated war wounds.[32] A number of reports suggested that a prosthetic graft yields satisfactory results, but poor long-term patency and infection risk in war wounds underlie the current recommendation to avoid prosthetic grafts in war wounds.[33–35] In this study, no initial arterial repairs were performed with a prosthetic graft, and there were no arterial ligations. Most of the repairs were saphenous interposition grafts because of the segmental loss of the popliteal artery that occurs with fragmentation wounds. Interposition is much more difficult than lateral suture repair, and this difficulty should be accounted for when comparing reported amputation rates. Two casualties, once evacuated to the United States, had limited remaining autogenous vein and required prosthetic grafts in the secondary management of failed (1 rupture and 1 graft thrombosis) initial vein grafts. Deciding on the optimal graft type (vein or pros-

thetic) is difficult when multiple injured extremities limit the availability of suitable autologous vein for graft use. Grafts without muscle coverage will fail regardless of the type of initial graft chosen. In a tertiary center with duplex mapping and optimal surgical conditions, replacing prosthetic grafts with controlled venous harvests may optimize outcomes. Finally, to avoid use of a prosthetic graft, one can use the amputated contralateral limb's saphenous vein (Fig. 2).[36]

For the 17 casualties with combined arterial and venous injuries, the decision to ligate or repair the venous injury was based on the patient's condition and the surgeon's preference. In this study, the order of venous and arterial repair was not recorded. Although the optimal order is often debated, we recommend arterial repair first and, if the patient's condition permits, the venous repair. Unfortunately, if only the surgeons had recorded the repair order, we could have evidenced which was superior.[37,38]

Complication rates remain very high for popliteal artery injuries and are similar to those of past conflicts, often related to infection and venous thromboembolism.[39] Repeated operations like debridements risk venous thromboses, and a liberal policy to place a retrievable inferior vena cava filter when the casualty arrives at a higher-echelon medical center outside the war zone has been recommended.[40] When counting complications, casualties who underwent thrombectomy were included because failure of thrombectomy suggested that an unrecognized distal injury existed and underscores the need for careful assessment in the leg or foot. Completion arteriography, although not always practical, may be indispensable in the detection of an occult injury and can be a useful adjunct when limited interventions are planned.[1,41]

Study Limitations

This study has several limitations. The retrospective design, small cohort, and use of registry data are the main limitations. War-time investigators are always challenged by the difficulty in collecting accurate data, particularly in records in austere settings with many surgeons at many hospitals on three continents. The casualties were young, previously healthy men, and their injury pattern or ability to withstand hemorrhagic shock, ischemia-reperfusion, coagulopathy, and hypothermia may be different from those of less-fit patients with similar arterial injuries. The meaning of the word amputation (injury, procedure, or outcome) is essential for clarity when discussing limb salvage; ambiguity in writings has made interwar comparisons difficult. Furthermore, exact comparisons are difficult because medical definitions, health-care records, changing tactics, and surgical care continue to evolve on the modern battlefield compared with prior wars. For clarity, much of the data on the reasons for immediate amputation (casualties with no repair of popliteal vascular injury or contralateral amputees in the study group) were not analyzed because of inadequate documentation or absent data and, therefore, could not be studied presently. The need for a theater-wide data collection sheet for major limb trauma, such as vascular injury, has become plain (Appendix). Collection of such data could better define categories like traumatic amputation (injury or completion), surgical amputation to control hemorrhage (with or without adjuncts like

a tourniquet or hemostatic dressings), surgical amputation after failed attempts at limb salvage (early, mid, and late graft failures), and elective amputations (poor function, pain, and nonhealing). The timing (immediate, early, and delayed) of various amputation categories is also of clinical interest, and to our knowledge, a consensus on this classification has not been defined or collected in the current war.

CONCLUSION

This study, a worst-case study, showed comparable results with historical controls regarding limb salvage rates (71% for Iraq vs. 56%–69% for the Vietnam War) for a combat-related injury to the popliteal artery. In the US military hospitals capable of DCR, we showed that severely injured casualties can undergo safe popliteal arterial revascularization with an amputation-free survival rate of 67% at 4 years. The current amputation rate suggests that these worst cases of popliteal vascular injury and significant transfusion requirements may not be an indication to resort to a life-over-limb approach. Thirty-day survival (98%) data and long-term complication free rates (35%) fill a current knowledge gap. Future studies directed at defining the cause of limb salvage failures may serve to improve combat casualty care by lowering the overall amputation rate.

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DISCUSSION

Dr. David S. Kauvar (Fort Sam Houston, TX): This manuscript presents descriptive data on severely injured U.S. military casualties undergoing popliteal vascular repair. The authors report good results in terms of overall and amputation-free survival, and their results seem to indicate improvement over the results of popliteal injury over previous conflicts. The manuscript is strengthened by the long-term follow-up obtained by the authors—commendable given the difficulties with the acquisition of wartime data.

I do have several questions and comments for the authors:

1. Please define "military injury severity score" for the reader who might be unfamiliar with this term and its derivation. If used in the abstract, a definition is needed as well.
2. In the results section, first paragraph, you mention "48 pulseless limbs." When in the evacuation chain was the sentinel vascular examination performed and by whom?
3. Do you have reliable data on the use of tourniquets for hemorrhage control in this population? How about nerve injuries? If so, such data would be a valuable addition to this manuscript.
4. Please give an idea of the distribution of concomitant traumatic injuries.
5. Did the mechanism of injury (gunshot wound versus explosion) influence the outcomes?
6. You mention in the second paragraph of the results section a "short pre-hospital transport time" of around thirty minutes—is there any data to back this up?
7. What was the frequency of the use of fasciotomy in this cohort—was there any influence on limb outcome?
8. Do you have data on the use of heparin, especially in shunted patients?
9. In the results section, subsection on "Overall Complications. . .," I do not understand the derivation of the data presented in the following sentence: "Two of the remaining 21 (9.5%) grafts. . .." Please make this data clearer.
10. Please give the median follow-up interval for the cohort.
11. I would be interested to see the authors comment in the discussion section on their thoughts regarding the influence of shock and presenting physiology on the decision-making and limb outcomes in their population.

I commend the authors on this work, which synthesizes disparate pieces of difficult-to-obtain data.

Dr. Charles J. Fox (Walter Reed Army Medical Center, Washington, DC): Thank you for the opportunity to discuss your insightful questions.

The military injury severity score (ISS) provides an overall score for military patients suffering from multiple combat-related injuries. The scoring system is based on the severity of the injuries. The body is divided into six regions and each is assigned a score from 1 to 6; 1 being a minor injury to 6 being a non-survivable injury, the highest three regions are then squared. The sum of these values gives the overall injury severity score, the highest possible score is a 75. The ISS was calculated by a certified coder at the Institute of Surgical Research at Fort Sam Houston, Texas.

Numerous injuries reflected in the reported ISS included multiple fractures, extensive soft tissue wounds, burns and penetrating abdominal and pelvic injuries. When looking at the mechanism of injury, casualties suffering from blast injuries accounted for all but one amputation. A possible explanation for this may be due to the extensive soft tissue loss associated with the fragmentation wounds. The vascular examination was performed by the primary surgeon when the casualty arrived in the emergency department.
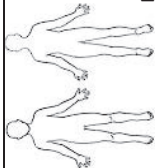
During 7 months of our study period in 2006, at the same combat support hospital, the publication by "Kragh JF Jr, Walters TJ, Baer DG et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. Ann Surg. 2009;249:1-7." describes the use of tourniquets for controlling hemorrhage. Tourniquet-associated nerve injury was reported in four (1.7%) of 232 patients.

Regarding fasciotomy, of the 46 casualties 20 of them had an immediate fasciotomy, yet we suspect that there were more fasciotomies performed and this is inconsistently documented. Therefore, no conclusions can be made in this paper with respect to fasciotomy and limb salvage.

Temporary vascular shunts were used very infrequently at a level III facility, and ischemic times were limited due to rapid casualty evacuation. Short pre-hospital transport times of "around thirty minutes" was the general rule, however, transportation data was inconsistently documented and is a recognized study limitation. Heparin was used sparingly and again, not always documented. Finally, the median and mean follow-up intervals are the similar for this cohort. The mean is 48.0 and the median is 48.4 months.

APPENDIX

AMPUTATION DATA COLLECTION SHEET

Patient Name:		ID #	Lived/Died:	Injury Date:	Death Date:
Last Follow-up Date:		Age (years):	Sex: □ M □ F	Nationality:	Job:

Limb Injury — Left upper extremity (LUE), right UE (RUE), left lower extremity (LLE), right LE (RLE)	Traumatic Injury — Total Amputation (T), Subtotal Amputation (S), Mangled without amputation injury (M), Other (O)	Amputation Level — Trans-torso (To), Trans-pelvic/scapula (P/Sc), Through hip/shoulder (H/Sho), Trans-femoral/humeral (F/H), Through knee/elbow (K/E), Trans-tibial/radial (Ti/R), Through ankle/wrist (A/W), Trans-foot/hand (Ft/Hd), Digits (D)	Perfusion — Pulseless (Pu), Pallor (Pa), Cool limb (CL)	Ischemia Duration (min) — Sum: time from artery injury to repair with duration of tourniquets or shock	Needs Associated with Amputation — Hemorrhage control (HC), Shock (Sh), Coagulopathy (Co), Acidosis (H^+), Hypothermia (HT), Other (O)	Amputation Surgery — Date of Amp Surgery: Categorize time of surgery: At Time of Injury (TOI) Immediate (after TOI) but ≤2d of TOI) Early (>2 to 30d) Late (>30d)	Result/When — Limb Outcome: Saved (S), Lost Explain why lost and give date lost.
□ LUE	□ T □ S □ M □ O	□ To □ P/Sc □ H/Sho □ F/H □ K/E □ Ti/R □ A/W □ Ft/Hd □ D	□ Pu □ Pa □ CL	___ min	□ HC □ Sh □ Co □ H^+ □ HT □ O	□ TOI □ ≤2d □ >2-30d □ >30d	□ Saved □ Lost: Date:
□ RUE	□ T □ S □ M □ O	□ To □ P/Sc □ H/Sho □ F/H □ K/E □ Ti/R □ A/W □ Ft/Hd □ D	□ Pu □ Pa □ CL	___ min	□ HC □ Sh □ Co □ H^+ □ HT □ O	□ TOI □ ≤2d □ >2-30d □ >30d	□ Saved □ Lost: Date:
□ LLE	□ T □ S □ M □ O	□ To □ P/Sc □ H/Sho □ F/H □ K/E □ Ti/R □ A/W □ Ft/Hd □ D	□ Pu □ Pa □ CL	___ min	□ HC □ Sh □ Co □ H^+ □ HT □ O	□ TOI □ ≤2d □ >2-30d □ >30d	□ Saved □ Lost: Date:
□ RLE	□ T □ S □ M □ O	□ To □ P/Sc □ H/Sho □ F/H □ K/E □ Ti/R □ A/W □ Ft/Hd □ D	□ Pu □ Pa □ CL	___ min	□ HC □ Sh □ Co □ H^+ □ HT □ O	□ TOI □ ≤2d □ >2-30d □ >30d	□ Saved □ Lost: Date:

Injury Notes	Prehospital Notes	Exam Notes or Complications	Surgery Notes	Care Notes	Tissue Injury (I) Loss (L) — Muscle (Mu), Bone (B), Vessel (V), Skin (Sk), Nerve (N)	Situations for Amp — Entrapment (E), Mass cal (MC), Multi-injury (MI), No prosthesis (No), Limited surgery (LS), Limited rehab (R)	Amputation was — Injury (I), Completion (C), Salvage Failed (F), Elective (E)
□ LUE					□ Mu □ B □ V □ Sk □ N □ R	□ E □ MC □ MI □ No □ LS □ R	□ I □ C □ F □ E
□ RUE					□ Mu □ B □ V □ Sk □ N □ R	□ E □ MC □ MI □ No □ LS □ R	□ I □ C □ F □ E
□ LLE					□ Mu □ B □ V □ Sk □ N □ R	□ E □ MC □ MI □ No □ LS □ R	□ I □ C □ F □ E
□ RLE					□ Mu □ B □ V □ Sk □ N □ R	□ E □ MC □ MI □ No □ LS □ R	□ I □ C □ F □ E

Draw & write notes on & near outline   Front Right   Back Right   Explain details; e.g., change in level over time: